

METHOD, SYSTEM AND SIGNALING GATEWAYS AS AN ALTERNATIVE TO SS7 SIGNAL TRANSFER POINTS

TECHNICAL FIELD

5 The present invention relates generally to communications using Internet Protocol (IP) for Signaling System 7 (SS7) signaling traffic and more specifically to the transportation of SS7 signaling traffic over an IP-based network. More specifically, the present invention relates to the use of signaling gateways capable of utilizing the IP backbone network as an alternative to traditional SS7 signal transfer points and an SS7 backbone network.

10

BACKGROUND OF THE INVENTION

Internet Protocol (IP) has become a popular communications standard enjoying wide-scale deployment and use. For example, the Internet is now a worldwide network of communications equipment and service providers which use IP as a common signaling protocol for communicating. On the Internet, messages are transmitted from one user to another over a vast infrastructure of routers, servers, gateways and communication devices. Typically, users on either end of the network operate computers equipped with appropriate software and equipment. The underlying link level protocols handle the messaging functions on both ends of the communication channel.

15

20

Transmission Control Protocol/Internet Protocol (TCP/IP) is a connection-oriented transport layer protocol that uses IP as its underlying networking protocol. TCP governs the exchange of sequential data, while IP routes outgoing and recognizes incoming messages. TCP has recently been joined by Stream Control Transmission Protocol (SCTP) as a transport protocol for telephony applications.

25

5 The widespread use of IP as a networking protocol has led to an intense
10 push for the integration of IP-based services with other networks such as
 common channel signaling systems, asynchronous transfer mode networks, and
 wireless. A form of common channel signaling is channel signaling system
 number 7 (SS7 or C7) which is a global standard for telecommunications defined
 by the International Telecommunication Union (ITU) and specifically the
 Telecommunications Standardization Section of the ITU (ITU-T). While IP
 networks communicate using flexible and easily modifiable connections, SS7
 uses a dedicated network to carry signaling traffic. In essence, the SS7 standard
 defines the procedures and protocols by which network elements in the public
 switch telephone network (PSTN) exchange information over a digital signaling
 network including wireless (e.g. cellular), and wireline call setup, routing and
 control. The ITU definition of SS7 allows for variance of the procedures and
 protocols such as those promulgated by the American National Standards
 Institute (ANSI) and Bell Communications Research (Bellcore) standards used in
 North America as well as the European Telecommunication Standards Institute
 (ETSI) standards used in Europe.

15 Essentially, an SS7 network and the defined protocols are used for
20 implementing call signaling functions including basic call setup management and
 tear down. In addition, SS7 specifies various wireless services such as personal
 communication services (PCS), wireless roaming and mobile subscription
 authentication. Recently, the SS7 protocol has been used for local number
 portability (LNP) as well as toll free and toll wireline services. Other services that
25 benefit from the SS7 protocol include enhanced call features such as call
 forwarding, calling party name and number display and three way calling as well
 as a wide array of emerging applications standards that provide for efficient and
 secure worldwide telecommunication.

5 With an SS7 network, messages are exchanged between network elements over 56 or 64 kilobits per second (kbps) using bi-directional channels called signaling links. Signaling occurs-out-of-band on dedicated channels rather than in-band on voice channels. Compared to in-band signaling, out-of-band signaling provides faster call setup times, more efficient use of voice circuits, and support for intelligent network services which require signaling to network elements without voice trunks. In addition, out-of-band provides for improved control over fraudulent network use. These advantages have made the SS7 protocol a popular choice for telephony.

10 The hardware and software functions of the SS7 protocol are divided into functional abstractions called levels. These levels map loosely to the Open Systems Interconnect (OSI) 7-layer model defined by the International Standards Organization (ISO). An Integrated Services Digital Network (ISDN) user part (ISUP) defines the protocol used to setup, manage and release trunk circuits that carry voice data between terminating line exchanges, e.g., between a calling party and a called party.

15 Currently, SS7 requires a dedicated network to handle the transport of signaling traffic. Some effort has been made to try to utilize other network resources, like an IP-based network, for transferring SS7 signaling traffic in an attempt to offer load sharing and save costs associated with deploying and utilizing a specialized, dedicated network. The internetworking between SS7 signaling traffic and IP is provided by a gateway that includes the conversion mechanism between the two protocols.

25 One such solution is offered by the company Tekelec which manufactures and sells a gateway capable of communicating SS7 signaling traffic over an IP

network. The Tekelec product uses a proprietary signaling protocol known as Transport Adapter Level Interface (TALI) that is designed to use standard TCP as the transport layer. In addition, the Tekelec solution requires a smart STP to properly route SS7 signaling traffic over the IP network. This requires that traffic be routed to an intermediary node in the IP network resulting in an additional hop for messages to reach their destination.

Thus, with prior art SS7/IP signaling mechanisms, a message must first go from an origination Signaling Gateway (SG) on the edge of the IP network to a "smart" Signal Transfer Point (STP). The SG transports the SS7 message to the STP using IP and the STP interprets the SS7 message and routes it to its destination. Thus, the smart STP routes the message to a destination Signaling Gateway at the border of the IP network which recovers the SS7 signaling traffic from the IP message stream. Thus, since a dedicated conversion node is needed, the signal traffic must traverse an extra hop in the transmission pathway resulting in unnecessary delay and complexity of a dedicated network path and conversion node. Moreover, the use of a proprietary IP protocol, such as TALI, is disadvantageous since it limits inter-networking between equipment not supporting the protocol in the network.

Accordingly, a way of routing SS7 signaling traffic over IP that is free of proprietary protocols and that eliminates the need for a dedicated conversion node would provide numerous advantages.

SUMMARY OF THE INVENTION

5 The present invention provides a method, system and device, in the form of a signaling gateway, that permits the routing of SS7 signaling traffic over an IP network and eliminates the use of a dedicated traffic conversion path and node. With the present invention, an IP backbone can be used for transmission of SS7 signaling traffic from an originating SG to a destination SG without an intermediary SS7-knowledgeable hop and without the use of proprietary conversion protocols.

10 According to one embodiment of the invention, disclosed is a method of routing Signaling System 7 (SS7) signaling traffic over an Internet Protocol (IP) network. The method comprises the steps of a first signaling gateway (SG) receiving SS7 signaling traffic from a first signaling point. Next, the first SG transfers the signaling traffic over the IP network by routing the signaling traffic in an IP message stream to a second SG supporting peer-to-peer communications with the first SG over the IP network. Finally, the second SG receives the IP message stream and recovers the SS7 signaling traffic from the IP message stream. Peer-to-peer communications between the first and second SG is supported by conversion layers within the SG, in the form of an SCTP and M3UA protocols that allows peer IP signaling between the two SGs. The first SG may transfer the signaling traffic by routing the signaling traffic a Network Indicator (NI) and a Destination Point Code (DPC) to determine how to best route the signaling traffic. Global title translation can be used to reveal the DPC of the signaling traffic.

20 According to a second embodiment, disclosed is a signaling gateway for routing Signaling System 7 (SS7) signaling traffic over an Internet Protocol (IP) backbone. The signaling gateway comprises an SS7 interface to an SS7

signaling link and an IP interface to an IP signaling link. Conversion means between the SS7 interface and the IP interface allow conversion of SS7 signaling traffic received from the SS7 signaling link to IP traffic suitable for transmission over the IP signaling link. The conversion means comprises SS7 to IP conversion layers in the form of Stream Control Transmission Protocol (SCTP) and Message Transfer Part 3-User Adaptation Layer (M3UA) protocols layers which permit routing of SS7 signaling traffic over the IP signaling link based on the Network Indicator and Destination Point Code (DPC) of said traffic. The signaling SS7 to IP conversion may also include an SCCP protocol layer which allow global title translation of SS7 signaling traffic in order to reveal the DPC.

Further disclosed is a system for routing SS7 signaling traffic over an IP backbone. The system comprises a first signaling gateway (SG) configured to convert SS7 signaling traffic into an IP message stream and a second SG configured to recover SS7 signaling traffic from an IP message stream. The system further comprises an IP link providing a signaling channel between the first SG and the second SG. The SGs are configured so that the first SG and second SG are in peer-to-peer communication over the IP network and so that the first SG and second SG are capable of transferring SS7 signaling traffic via an IP interface by converting SS7 signaling traffic into an IP message stream. The SGs can be configured to use a Network Indicator (NI) and a Destination Point Code (DPC) to determine how to route said signaling traffic and can use global title translation to determine the DPC. Point code conservation may be permitted by having the first and second SG share the same DPC.

A technical advantage of the present invention is that it allows a telecommunications provider to send signaling traffic off band over an existing IP network. This allows the provider additional flexibility and bandwidth as it

eliminates the requirement for a dedicated transit switch to handle the signaling traffic.

Another technical advantage of the present invention is that it allows direct connections between a pair of SGs on the edge of an IP network without the need to go through an intermediary node with SS7 routing intelligence.

BRIEF DESCRIPTION OF THE DRAWINGS

The above features and advantages of the present invention will be more clearly understood from consideration of the following detailed description in connection with the accompanying drawings in which:

Figure 1 illustrates a typical SS7 network of the prior art;

Figure 2 illustrates an SS7 protocol stack of the prior art along side the OSI reference model;

Figure 3 depicts a signaling gateway using an IP network of the prior art;

Figure 4 illustrates use of signaling gateways to transfer signaling traffic over an IP link, according to an embodiment of the present invention.

Figure 5 shows the protocol stacks to implement the invention, according to the preferred embodiment;

Figure 6 illustrates a system for routing SS7 signaling traffic over an IP network, according to an embodiment of the present invention; and

Corresponding numerals and symbols in the different figures refer to corresponding parts unless otherwise indicated.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to Figure 1, a node diagram of a typical channel signaling system number 7 (SS7) network 50 is shown. Service Switching Points (SSP) 56 comprises SS7 data traffic switches between an end network and the SS7 network. For example, SSP 56 can provide an interface between a telecommunications switch such as a Mobile Switching Center (MSC) 52 and other nodes of the SS7 network 50. Signaling Transfer Points (STP) 58 are used for routing SS7 signaling traffic in the network 50 as well as routing from one node to another node of the SS7 network 50 eliminating the need for direct links between every pair of signaling points in the network. Since the traffic can originate from various end networks, an specific STP 58 may perform global title translation, a procedure by which a destination point code is revealed from the incoming traffic stream, to determine the destination of the traffic. Other functions may also be provided by the STP 58, such as stream control, failure recovery and rerouting as is well known in the arts.

The SSPs 56 are switches that originate and terminate as tandem calls. Thus, an individual SSP sends signaling traffic to other SSPs for setup, management and release of voice circuits required to complete a call. An SSP may also send a query message to a centralized data base such as the Service Control Point (SCP) 70 to determine how to route a call, e.g., a toll free number calling in North America. The SCP 70 sends a response to the originating SSP 56, for example, containing the routing numbers associated with a dialed number. An alternate routing number may be used by the SSP 56 if the primary number is busy or the call is unanswered within a specified time. Actual call

features vary from network to network and from service to service. Network traffic between signaling points may be routed STP 58. An SSP 56 is coupled to the STP 58 through one or more SS7 links 57. In operation, the STP 58 routes each incoming message to an ongoing signaling link based on routing information contained in the SS7 signaling traffic.

Because the SS7 network 50 is widely utilized for call switching, the STP 56 and STP 58 are usually deployed in mated pair configurations. Typically, pairs of elements are located in separate physical locations to assure network wide service in the event of an isolated failure. The SS7 links 57 between signaling points 56, 58 can also be provisioned in pairs. Traffic is shared across all links in the link set and if one of the links fails the signaling traffic is rerouted over another link in the link set. The SS7 protocol provides both error correction and retransmission capabilities to allow continued service in the event of signaling point or link failures.

With reference to Figure 2, therein is shown the SS7 protocol stack 80 aside the OSI reference model. The message transfer part (MTP) layer 82 is divided into three levels. The lowest level, MTP level one 84 is equivalent to the OSI physical layer and defines the physical, electrical and functional characteristics of the digital signaling link. Next, MTP level two 86 ensures accurate end-to-end transmission of a message across a signaling link. In essence, the MTP level two 86 implements flow control, message sequence validation and error checking so that when an error occurs on a signaling link, the message (or set of messages) is retransmitted. As indicated in Figure 2, the MTP level two 86 is equivalent to the OSI data link layer.

The final layer of MTP 82, MTP level three 88 provides message routing between signaling points 58 in the SS7 network 50. MTP level three 88 reroutes traffic away from failed links and controls traffic when congestion occurs. MTP level three 88 functions as the OSI network layer of the OSI reference model.

5

The ISUP layer 90 of the SS7 protocol stack 80 defines the protocol used to setup, manage and release trunk circuits that carry voice and data between terminating line exchanges, e.g., between a calling party and a called party. The ISUP layer 90 is used for both ISDN and non-ISDN calls. However, calls that are originate and terminate at the same switch do not use ISUP signaling. The protocol stack 80 also includes a telephone user part (TUP) layer 92 which supports basic call setup and tear down functions in some parts of the world. The TUP layer 92 handles analog circuits only and in some countries, the ISUP layer 90 has been used to replace TUP layer 92 for call management.

10

15

A signal link connection control part (SCCP) 94 provides connection-less and connection-oriented network services and global title translation capabilities above the MTP level three 88. A global title is an address, e.g., a dialed 800 number, calling card number, or mobile subscriber identification number, which is translated by the SCCP layer 94 into a destination point code (DPC) and subsystem number. A subsystem number uniquely identifies an application at the base destination signaling point. The SCCP layer 94 is used as a transport layer for TCAP based services.

20

25

The final part of the SS7 protocol stack 80 includes the transaction capabilities application part (TCAP) 96 which supports the exchange of noncircuit related data between applications across the SS7 network 50 and the SCCP 94 connectionless service. As such, queries and responses sent between

the SSP 56 and the SCP 70 (Figure 1) are carried in a TCAP message. For example, an SSP 56 sends a TCAP query to determine the routing number associated with the dialed number and to check the personal identification number of a calling card user. In mobile networks (IS-41 and GSM), TCAP 96 carries mobile application part messages sent between mobile switches and data bases to support user authentication equipment identification and roaming.

Having described the essential elements of an SS7 network 50 and the SS7 signaling protocol 80, reference is now made to Figure 3 which illustrates the use of an IP-based network for routing SS7 signaling traffic. As mentioned, the use of an IP backbone for transmission of SS7 signaling traffic provides efficiencies in terms of network costs of operation since it eliminated the need to have a separate signaling network just for the SS7 traffic. In Figure 3, a communications system utilizing IP to transfer SS7 signaling traffic is shown and denoted generally as 100. Signaling End Points (SEP) 102A sends SS7 signaling traffic via SS7 link 57 to a signaling gateway 104A. Next, signaling gateway 104A sends the traffic to STP 105 within the IP network 106 by encapsulating the SS7 message into an IP-based message. The STP 105 includes functionality for determining how to route the traffic in an IP message stream that allows the traffic to reach its destination. Thus, the STP 105 determines proper routing for the signaling traffic and sends it to SG 104B. SG 104B then sends the routing on its way to signaling end point 102C.

Thus, communications between SG 104a and 104B over IP network 106 must go through STP 105. The use of STP 105 adds additional hop with SS7 knowledge in the transmission path and prohibits direct transmission of SS7 signaling traffic in the IP network 106 from the originating SG 104A to the destination SG 104B. Furthermore, since STP 105 determines the outgoing

route, IP is being used as a transport mechanism rather than a routing mechanism on the IP network 106 resulting in inefficient use of the IP network 106. Moreover, in order to provide the conversion and route determination functions, STP 105 is equipped with a proprietary protocol that requires the use of protocol compliant devices at the STP 105 as well as other nodes in the network 100 that must recognize the STP 105. Therefore, for these and other reasons the use of STP 105 for routing SS7 signaling traffic is disadvantageous.

Referring to Figure 4, a system for routing Signaling System 7 (SS7) signaling traffic over an Internet Protocol (IP) according to the invention is shown and denoted generally as 110. System 110 includes SEP 112A connected via SS7 link 157 to SG 114A. SG 114A has an SS7 interface 116 which allows it to receive information from nodes in an SS7 network, such as SEP 112A and SEP 112B. In addition, SG 114A includes has an IP interface 118 which allows it to communicate over IP link 109. SG 114B provides a gateway to the SS7 traffic destination point and likewise includes an IP interface 120 which allows it to communicate over IP link 109 in peer-to-peer communications with signaling gateway 114A. In this way, direct communications between a pair of SGs, such as SG 114A and SG 114B, is provided.

SG 114B is capable of receiving an IP message stream directly from SG 114A without passing through an intermediary node, such as STP 105. The destination SG 114B then recovers SS7 signaling traffic from the IP messaging stream and sends it over SS7 link 159 to SEP 112C. Thus, SG 114a and 114B are in direct communication over IP link 109 and no intermediate steps or nodes are required to successfully transfer the SS7 signaling traffic over the IP link between SG 114a and 114B.

Thus, the present invention achieves technical advantages as a method, system and signaling gateway for permitting peer-to-peer IP communications between two SGs on the edge of an IP network, such as IP network 106. Preferably, the SGs 114A, 114B are equipped with conversion means, in the form of protocol conversion layers that allow them to receive SS7 signaling traffic from a node in an SS7 network, convert the traffic into corresponding IP formatted messages or IP message stream, and transmit the IP message stream within the IP network using IP to achieve the routing. This lead to an efficient use of the IP backbone and protocol and eliminates the need for a dedicated network to carry the SS7 signaling traffic.

In Figure 5, the SS7-to-IP conversion means within the SGs 114A, 114B is shown in more detail. Essentially the conversion means comprises a set of conversion layers or protocol layers within the SGs 114A, 114B that permit direct peer-to-peer communications between the SGs 114A, 114B. Essentially, the protocol layers provide the SS7 interface and the IP interface within the SGs.

As shown, SS7 signaling traffic is transmitted by a first STP or SEP 160A to a first SG 114A. Within the STP/SEP 160A, the TCAP layer 96, SCCP layer 94, MTP3 layer 98, a MTP2 layer 96, and a MTP1 layer 84 are applied to the traffic according to well known protocol standards. The signaling traffic then proceeds through an SS7 link 157 and into SG 114A. SG 114A receives the SS7 signaling traffic and applies MTP1 layer 84, MTP2 layer 86, a MTP3 layer 88, optionally uses SCCP layer 94, Nodal Interworking Function (NIF) layer 114, MTP3-User Adaptation Layer (M3UA) 112 and Stream Control Transmission Protocol (SCTP) 110 as appropriate. Alternatively, the STP/SEP 160A may utilize ISUP or TUP. NIF Layer 114 within SG 114A serves as the interface between the MTP3 layer 88 and M3UA layer 112. NIF layer 114 has no visible

peer protocol within STP 58 but provides network status information to one or both sides of the network.

SCTP 110 is familiar to those skilled in the art. SCTP is a specialized transportation protocol that has been developed for communications applications. SCTP 110 is designed to take the place of TCP, which is commonly used in Internet transactions across an IP network. M3UA 112 is a protocol that supports the transport of any SS7 MTP3-User signaling (e.g., SCCP messages) over an IP network using the services of the SCTP layer 110. Additionally, M3UA layer 112 contains protocol elements enabling a seamless operation of the MTP3-User peers in the SS7 and IP domains. M3UA layer 112 is designed to be used between a SG, such as SG 114A, and a Media Gateway Controller (MGC) or IP-resident Database. The invention takes advantage of this feature of M3UA to permit IP-enabled end nodes that conform to M3UA/SCTP protocol to inter-operate within the IP network and to support communications over the IP link 109. Thus, the fact that SGs 114A, 114B include M3UA layer 112 and SCTP layer 110 provides a mechanism for peer-to-peer communications over IP link 109.

Figure 6 illustrates the routing of SS7 signaling traffic over an IP network 106 and in a communication system 130 employing SGs 114A and 114B, according to one embodiment of the invention. On the origination end 132, a first SG 114A receives SS7 signaling traffic from a first signaling point, either SEP 112A or SEP 112B. In the simplest case, the SG 114A will route the traffic it receives from its SS7 interface 116 using the Network Indicator (NI) and Destination Point Code (DPC) of the traffic. In this case, the SCCP layer 94 is not used with only the SCTP layer 110 associations used for passing the traffic between the pair of SGs 114A, 114B. The SCTP layer 110 associations may

also be used to pass management related messages between the SGs 114A, 114B such as messages related to destination availability.

If necessary, the SCCP layer 94 can be used to support global title translation as shown in block 134. In this case, the SG 114A will make use of the SCCP layer 94 and translate the incoming SS7 signaling traffic in order to reveal its DPC. Thereafter, the SS7 signaling traffic is routed according to its destination. Thus, the SG 114A applies global title translation to determine the destination point code, then it uses the network identifier and the DPC to determine how to route the SS7 signaling traffic. Then, at block 136, SG 114A sends the SS7 signaling traffic in an IP messaging stream across IP network 106 to SG 114B. In block 138, the destination SG 114B receives the IP message stream and recovers the SS7 signaling traffic. At block 140, SG 114B sends the SS7 signaling traffic to signaling end point 112B over a SS7 signaling link 159.

Advantages of the system, method and signaling gateway of the present invention are numerous and include the elimination of an intermediary conversion or "smart" STP that determines how to route the SS7 signaling traffic. Since peer-to-peer communications between a pair of SGs is provided, efficient use of the IP network is achieved. Moreover, the routing of SS7 signaling traffic over an IP network is achieved without the use of proprietary signaling protocols since SCTP and M3UA are explicitly described in known specifications. This permits devices supporting M3UA 112, SCTP 110 and IP to interact in the SS7 IP network 106 without using a dedicated SG. The invention takes advantage of these protocols by equipping a pair of SGs on the border of an IP network with these protocols allowing inter-networking between the pair.

Additional advantages of the invention are the ability to support global title translation and conserve point codes since each SG 114A, 114B (as well as others) can be assigned the same SS7 point code.

5

While the invention has been described with reference to illustrative embodiments, this description is not intended to be construed in a limiting sense. Various modifications and combinations of the illustrative embodiments as well as other embodiments of the invention will be apparent to persons skilled in the art upon reference to the description.

10

11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1020
1021
1022
1023
1024
1025
1026
1027
1028
1029
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1040
1041
1042
1043
1044
1045
1046
1047
1048
1049
1050
1051
1052
1053
1054
1055
1056
1057
1058
1059
1060
1061
1062
1063
1064
1065
1066
1067
1068
1069
1070
1071
1072
1073
1074
1075
1076
1077
1078
1079
1080
1081
1082
1083
1084
1085
1086
1087
1088
1089
1090
1091
1092
1093
1094
1095
1096
1097
1098
1099
1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1110
1111
1112
1113
1114
1115
1116
1117
1118
1119
1120
1121
1122
1123
1124
1125
1126
1127
1128
1129
1130
1131
1132
1133
1134
1135
1136
1137
1138
1139
1140
1141
1142
1143
1144
1145
1146
1147
1148
1149
1150
1151
1152
1153
1154
1155
1156
1157
1158
1159
1160
1161
1162
1163
1164
1165
1166
1167
1168
1169
1170
1171
1172
1173
1174
1175
1176
1177
1178
1179
1180
1181
1182
1183
1184
1185
1186
1187
1188
1189
1190
1191
1192
1193
1194
1195
1196
1197
1198
1199
1200
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
1219
1220
1221
1222
1223
1224
1225
1226
1227
1228
1229
1230
1231
1232
1233
1234
1235
1236
1237
1238
1239
1240
1241
1242
1243
1244
1245
1246
1247
1248
1249
1250
1251
1252
1253
1254
1255
1256
1257
1258
1259
1260
1261
1262
1263
1264
1265
1266
1267
1268
1269
1270
1271
1272
1273
1274
1275
1276
1277
1278
1279
1280
1281
1282
1283
1284
1285
1286
1287
1288
1289
1290
1291
1292
1293
1294
1295
1296
1297
1298
1299
1300
1301
1302
1303
1304
1305
1306
1307
1308
1309
1310
1311
1312
1313
1314
1315
1316
1317
1318
1319
1320
1321
1322
1323
1324
1325
1326
1327
1328
1329
1330
1331
1332
1333
1334
1335
1336
1337
1338
1339
1340
1341
1342
1343
1344
1345
1346
1347
1348
1349
1350
1351
1352
1353
1354
1355
1356
1357
1358
1359
1360
1361
1362
1363
1364
1365
1366
1367
1368
1369
1370
1371
1372
1373
1374
1375
1376
1377
1378
1379
1380
1381
1382
1383
1384
1385
1386
1387
1388
1389
1390
1391
1392
1393
1394
1395
1396
1397
1398
1399
1400
1401
1402
1403
1404
1405
1406
1407
1408
1409
1410
1411
1412
1413
1414
1415
1416
1417
1418
1419
1420
1421
1422
1423
1424
1425
1426
1427
1428
1429
1430
1431
1432
1433
1434
1435
1436
1437
1438
1439
1440
1441
1442
1443
1444
1445
1446
1447
1448
1449
1450
1451
1452
1453
1454
1455
1456
1457
1458
1459
1460
1461
1462
1463
1464
1465
1466
1467
1468
1469
1470
1471
1472
1473
1474
1475
1476
1477
1478
1479
1480
1481
1482
1483
1484
1485
1486
1487
1488
1489
1490
1491
1492
1493
1494
1495
1496
1497
1498
1499
1500
1501
1502
1503
1504
1505
1506
1507
1508
1509
1510
1511
1512
1513
1514
1515
1516
1517
1518
1519
1520
1521
1522
1523
1524
1525
1526
1527
1528
1529
1530
1531
1532
1533
1534
1535
1536
1537
1538
1539
1540
1541
1542
1543
1544
1545
1546
1547
1548
1549
1550
1551
1552
1553
1554
1555
1556
1557
1558
1559
1560
1561
1562
1563
1564
1565
1566
1567
1568
1569
1570
1571
1572
1573
1574
1575
1576
1577
1578
1579
1580
1581
1582
1583
1584
1585
1586
1587
1588
1589
1590
1591
1592
1593
1594
1595
1596
1597
1598
1599
1600
1601
1602
1603
1604
1605
1606
1607
1608
1609
1610
1611
1612
1613
1614
1615
1616
1617
1618
1619
1620
1621
1622
1623
1624
1625
1626
1627
1628
1629
1630
1631
1632
1633
1634
1635
1636
1637
1638
1639
1640
1641
1642
1643
1644
1645
1646
1647
1648
1649
1650
1651
1652
1653
1654
1655
1656
1657
1658
1659
1660
1661
1662
1663
1664
1665
1666
1667
1668
1669
1670
1671
1672
1673
1674
1675
1676
1677
1678
1679
1680
1681
1682
1683
1684
1685
1686
1687
1688
1689
1690
1691
1692
1693
1694
1695
1696
1697
1698
1699
1700
1701
1702
1703
1704
1705
1706
1707
1708
1709
1710
1711
1712
1713
1714
1715
1716
1717
1718
1719
1720
1721
1722
1723
1724
1725
1726
1727
1728
1729
1730
1731
1732
1733
1734
1735
1736
1737
1738
1739
1740
1741
1742
1743
1744
1745
1746
1747
1748
1749
1750
1751
1752
1753
1754
1755
1756
1757
1758
1759
1760
1761
1762
1763
1764
1765
1766
1767
1768
1769
1770
1771
1772
1773
1774
1775
1776
1777
1778
1779
1780
1781
1782
1783
1784
1785
1786
1787
1788
1789
1790
1791
1792
1793
1794
1795
1796
1797
1798
1799
1800
1801
1802
1803
1804
1805
1806
1807
1808
1809
1810
1811
1812
1813
1814
1815
1816
1817
1818
1819
1820
1821
1822
1823
1824
1825
1826
1827
1828
1829
1830
1831
1832
1833
1834
1835
1836
1837
1838
1839
1840
1841
1842
1843
1844
1845
1846
1847
1848
1849
1850
1851
1852
1853
1854
1855
1856
1857
1858
1859
1860
1861
1862
1863
1864
1865
1866
1867
1868
1869
1870
1871
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
2051
2052
2053
2054
2055
2056
2057
2058
2059
2060
2061
2062
2063
2064
2065
2066
2067
2068
2069
2070
2071
2072
2073
2074
2075
2076
2077
2078
2079
2080
2081
2082
2083
2084
2085
2086
2087
2088
2089
2090
2091
2092
2093
2094
2095
2096
2097
2098
2099
2100
2101
2102
2103
2104
2105
2106
2107
2108
2109
2110
2111
2112
2113
2114
2115
2116
2117
2118
2119
2120
2121
2122
2123
2124
2125
2126
2127
2128
2129
2130
2131
2132
2133
2134
2135
2136
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
2151
2152
2153
2154
2155
2156
2157
2158
2159
2160
2161
2162
2163
2164
2165
2166
2167
2168
2169
2170
2171
2172
2173
2174
2175
2176
2177
2178
2179
2180
2181
2182
2183
2184
2185
2186
2187
2188
2189
2190
2191
2192
2193
2194
2195
2196
2197
2198
2199
2200
2201